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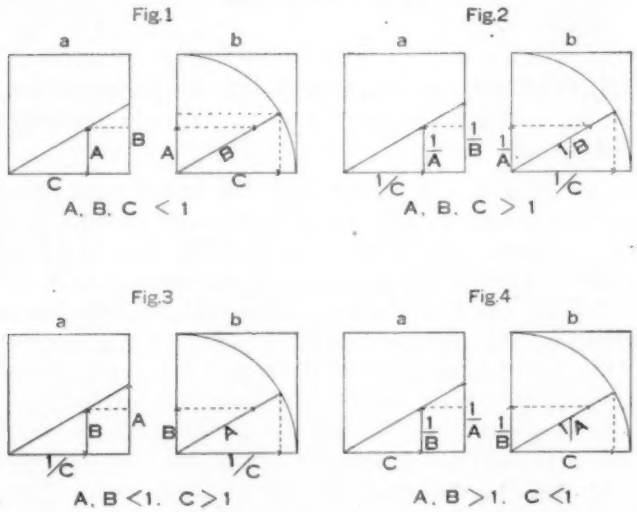
MATHEMATICS.—*A simple device for the graphical solution of the equation* $A = B \cdot C$. F. E. WRIGHT, Geophysical Laboratory.

The equation $A = B \cdot C$, in which the letters may represent numbers, or powers of numbers, or functions of variables as sines, cosines, tangents, logarithms, exponentials, etc., is essentially a simplified form of the equation of proportion, $A : B = C : D$ (rule of three) and is so common in physical and technical problems that different graphical methods have been suggested for its solution. A brief discussion of these methods was given several years ago by the writer[1] and the conclusion was reached that, "in all cases it is essential: (a) that the graphical means employed represent the relations adequately and as free from distortion as possible, and (b) that they be easy of application. The first principle requires that in any graphical representation the relative accuracy over the entire field be uniform and comparable to that which obtains in nature." In order to apply this principle effectively to the solution of a given equation it may be necessary to increase the uniformity in the plotting scale by taking some function of the values in the equation such as the logarithmic function or by raising the values to some power.

[1] Graphical methods in microscopical petrography. Am. Jour. Sci., Ser. 4, **36**: 509–542. 1913. See also R. A. Harris: On uses of a drawing board and scales in trigonometry and navigation. Science, N.S., **18**: 108–112. 1903. A diagram or chart for finding the sun's azimuth. Science, N.S. **22**: 469. 1905. C. Runge. Graphical Methods. New York. 1912.

In case A, B, C are functions of variables the equation $A = B \cdot C$ may be considered to express relations between the functions themselves, namely, between A, B, and C rather than between the variables; fundamentally, of course, the equation expresses relations between the variables, and the increments are so taken. The procedure adopted below amounts practically to the representation of each function by a scale so chosen that the resulting curves are straight lines. Straight lines can be



Figs. 1 to 4. Diagrams for graphical solution of certain equations.

drawn more readily and more accurately than curves; straight line diagrams are, moreover, easier to read. In the paper cited above a number of straight line diagrams are included which serve for the graphical solution of the equations encountered in microscopical petrography. These diagrams have been found in practice to be useful and time saving.

Recently a device has been adopted by means of which these equations and others of the same general form can be solved without requiring a special plot for each type of equation. Its con-

struction is based on the fact that an equation of the type $A = B \cdot C$ can always be expressed in such form that each factor has a value less than unity; for, in case a factor is greater than unity, the equation can be so written that the reciprocal of this factor is taken, which is then less than unity. The graphical solution of the equation by a straight line diagram can be accomplished either by a method of similar triangles or by a method of projection which, however, is also a method based on similar triangles. Both methods furnish results of the same order of exactness. Convenient forms of solution by the two methods are illustrated in figures 1 to 4, in which *a* refers in each case to the solution by similar triangles while *b* represents the solution by the method of projection. In figure 1 A, B, C are less than unity; in figure 2 A, B, $C > 1$; in figure 3 A, $B < 1$, $C > 1$; in figure 4 A, $B > 1$, $C < 1$.

In case it is inconvenient to use reciprocal values, it is possible to extend the range of the solution by changing the scale of the base line from 1 to 10, or to 100 or to any power of 10. This amounts simply to the shifting of the decimal point in one of the factors.

In the first method (figs. 1a, 2a, 3a, 4a) it is evident that if the values of A, B, C be plotted along the side lines the remainder of the solution is simply a matter of rectangular coordinates; and similarly for the solution by the method of projection.

The graphical solution on the basis of the above relations is readily accomplished by attaching permanently to a small drawing board of the usual size (19″ x 26″) a sheet of 1 mm. coordinate paper, 50 cm. square, at one corner of which a straight edge fits in a fixed socket so that it can be rotated about this corner as axis (fig. 5). To solve an equation such as $\sin A = \sin B \cdot \sin C$, two sine scales are first prepared by marking off the sine values directly (listed in sine tables) on a narrow slip of 1 mm. coordinate paper; these are then attached to the bottom and right side of the large sheet of coordinate paper as indicated in figure 5. In case B and C are known, set the edge of the rule at the value of B (40° in figure 5), find the abscissa C (41° in figure 5) and pass along its ordinate to the intersection with the edge of the rule;

the horizontal line through this point intersects the ordinate scale on the right at 25° which is the desired value of A.

To save time it is well to prepare at the outset pairs of scales of all the trigonometric functions, of logarithms, of reciprocals of numbers, their squares and square roots, and of any other functions which may be employed. Such scales are then always ready for use.

In case the observer has only a few types of the general equation to solve it is convenient to plot the scales for each type of

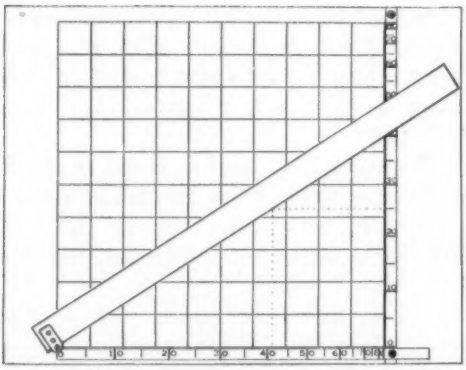


Fig. 5. Device for graphical solution of equation $A = B \cdot C$.

equation along the sides of a large sheet of coordinate paper, which then serves directly for the solution of the given equation. The bother of adjusting the scales to the sides of the plot is thus eliminated; a special sheet of coordinate paper is, however, required for each equation.

The degree of accuracy attainable by this device depends on the care taken to read the scales. In case the reading is correct to $\frac{1}{2}$ mm., the result is accurate to one part in a thousand.

Typical examples of the kinds of equations which can be solved by this graphical method of proportional parts are:

$$y = ax;\ pv = c;\ y = ax^2;\ y^2 = ax;\ y = a^x,$$
$$\text{or } \log y = x \log a;$$
$$y = x^n, \text{ or } \log y = n \log x.$$
$$\sin i = n \cdot \sin r;\ D = \sin A \cdot \sin A^1;\ \tan^2 V = \tfrac{A}{B};$$
$$\cot A = \sin B \cdot \sin C;\ \tan A = \sin B \cdot \cot C;$$
$$\cos A = \cos B \cdot \cos C;$$
$$\sin A = \sin B \cdot \sin C;\ \tan A = \sin B \cdot \tan C.$$

This list is by no means complete but it serves to indicate the variety of equations which are of the form $A = B \cdot C$ and which can therefore be solved graphically with a fair degree of accuracy.

GEOLOGY.—*A geological protractor.* F. E. WRIGHT, Geophysical Laboratory.

In geological field and map work a protractor is commonly used for plotting angles of strike and dip. For the drawing of a vertical cross section it is also desirable to determine the line of slope of any given bed on the section. Heretofore this has been accomplished either by graphical methods or by computation or by use of a graphical computation chart.[1] It is possible, however, by slightly modifying the protractor, to combine with it a slope angle computer such that the apparent dip of a bed can be read off directly for any angle of dip of stratum and for any azimuth of vertical section.

The principles on which the slope computer is based are presented in detail in the foregoing paper. The equation to be solved is of the form $\tan C = \sin B \cdot \tan A$ in which A is the true angle of dip, B the direction angle between the line of strike of the bed and that of the vertical section, and C the apparent dip angle on the vertical section. In solving this equation by the graphical method here proposed it is important to note that,

[1] A chart of this nature was first described by W. G. Woolnough, Proc. Australasian Association for the Advancement of Science, **1909**: 244–249. Practically the same chart was published later by D. F. Hewett without knowledge, however, of Woolnough's chart. Economic Geology, **7**: 190. 1912; and still later by H. Bancroft, Bull. Am. Inst. Mining Engineers, July 1914, p. 1769. A straight line chart was first prepared by the writer. Journ. Wash. Acad. Sci., **4**: 440–444. 1914.

because the radius of the protractor circle is taken to be unity whereas the tangent values may range from zero to infinity, three different cases are to be distinguished:

(a) Angles A and C are less than 45°; tan A, tan $C < 1$;
(b) Angles A and C are greater than 45°; tan A, tan $C > 1$;
(c) Angle A greater than 45° (tan $A > 1$);
angle C less than 45° (tan $C < 1$);
cos B is always less than unity.

To adapt the ordinary protractor to the solution of these problems a thin celluloid arm is so attached that it can be rotated

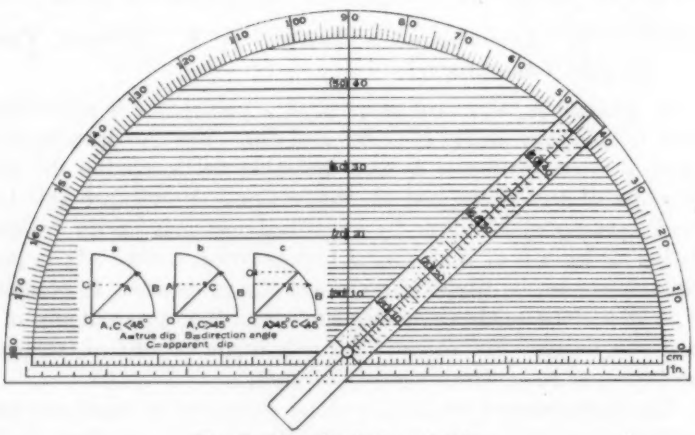


Fig. 1. A geological protractor.

about the center of the circle as an axis (fig. 1). On this arm a tangent scale is printed from 0° to 45°. A series of lines parallel to the base line of the protractor is printed on the face of the protractor as indicated in the figure. The extension of the rotating arm below the axis enables the geologist to use the protractor as a hand goniometer for the measurement of the angles between crystal faces. A scale of inches, divided into tenths, and a scale of millimeters are added below the base line of the protractor.

The methods of solution for the three cases noted above are indicated in figure 1*a*, *b*, *c*. In figure 1*a* OA (= tan A) is the true

dip; B, the direction angle, is read off directly on the graduated circle; OC (= tan C) is the apparent dip; thus the line of intersection of a stratum, dipping at an angle of 35° (OA), with a vertical section which includes an angle 44° 30′ (B) with the line of strike of the bed, has a slope angle (OC) of 26.1°. In figure 1*b* the angles A and C are greater than 45° and the numbers in parentheses on the scales are used; thus on a vertical section including an angle of 44° 30′ (B) with the line of strike of a bed dipping at an angle of 72° (OA) the apparent dip is 65.1°. In figure 1*c* the angle A is greater than 45° while C is less than 45°; in this case the numbers in parentheses on the scale of the rotating arm are used, while for the angle C the unbracketed numbers along OC are read; thus the trace of a bed, dipping at 60°, on a vertical section, which includes an angle of 24° with the line of strike of the bed, has a slope angle of 35.2°.

CHEMISTRY.—*The reaction of soil and measurements of hydrogen-ion concentration.* L. J. GILLESPIE, Bureau of Plant Industry. (Communicated by OSWALD SCHREINER.)

The reaction of soil is conceded to be of great influence upon soil fertility. Certain plants seem to require a certain degree of acidity, and may flourish at an acidity sufficient to be very harmful to others. That excessive acidity is a common cause of infertility in long-cultivated soils is generally recognized. On the other hand, sodium carbonate frequently occurs in the alkali soils of arid lands and imparts an excessive alkalinity. The study of the reaction of soil is therefore not only of considerable scientific but also of great practical importance.

Let us consider briefly the case presented by a sour soil. Two questions are of especial interest: (1) What is the quantity of acid substance? and (2) what is the intensity of the acidity? The amount of liming or other ameliorative treatment required to neutralize the acidity will depend upon the quantity of acid substance. It seems probable, on the other hand, that characteristic effects of acidity upon soil fertility will be more clearly correlated with the intensity of acidity than with the quantity

of acid substance. However this may be, a complete study of soil acidity must take both factors into consideration.

The lime requirement method of Veitch[1] and its numerous modifications, as well as all other titrimetric methods, for example, that of Baumann and Gully[2] and that of Daikuhara,[3] are an attempt to measure the quantity of acid substance, not the intensity of acidity. Furthermore, since a complete determination of the acids and bases in soils is as yet impossible, one cannot calculate the intensity of acidity from the quantity of acid substance, even if this could be determined by any of the methods yet proposed. The intensity of acidity, or of alkalinity, can only be determined experimentally by a measurement of the hydrogen-ion concentration.

In a study of the acids and colloids of humus Fischer[4] measured the hydrogen-ion concentrations of some soils by the electrometric method. He added, when necessary, just enough water to the soil to make possible an intimate wet contact between the soil and the wire electrode. He was able to demonstrate the acid nature of Hochmoor sphagnum (six samples). These showed a hydrogen-ion concentration of $9.6 \cdot 10^{-4}$ to $6.5 \cdot 10^{-4}$. Two Flachmoor samples were slightly acid ($6 \cdot 10^{-6}$ and $1.1 \cdot 10^{-6}$); another soil and a sample of compost were slightly alkaline ($2.7 \cdot 10^{-8}$ and $4 \cdot 10^{-8}$). Litmus did not respond to the weak acidities or alkalinities of these samples, but did give an acid reaction with the samples of Hochmoor sphagnum. Fischer states that it can be concluded from this that adsorption processes are not to be assumed to vitiate tests of acidity made by means of indicators.

Fischer had no other test with which to check his electrometric results, and his electrometric procedure was one that would not be expected to lead to a quick attainment of equilibrium. He was therefore obliged to continue the observations until the potential became constant. Seven to eight hours were required for this, and in the case of the soils which showed

[1] Journ. Am. Chem. Soc., **24**: 1120. 1902.
[2] Naturw. Ztschr. Forst- u. Landw., **6**: 1. 1908.
[3] Bull. Imp. Cent. Agr. Exp. Sta., Japan, **2**: 1. 1914.
[4] Kühn-Archiv (Halle), **4**: 1–136. 1914.

a hydrogen-ion concentration of about 10^{-6} or lower (and which were therefore feebly acid, neutral, or alkaline), constant potentials could not be obtained. It is objectionable to prolong the measurement unduly, as a platinized platinum electrode may become "sick," a phenomenon frequently observed after continued use. Hasselbalch and Gammeltoft[5] state that for this reason measurements on blood must not take more than one hour.

As a step toward the satisfactory determination of hydrogen-ion concentration in soil the writer has attempted to apply the hydrogen electrode to mixtures of soil and water and to apply indicators to extracts prepared by centrifuging such mixtures.

GENERAL PROCEDURE IN THE PRESENT INVESTIGATION

Since it seemed to be impossible to apply either the hydrogen electrode or indicators to soil in the condition in which we are most interested, namely, at optimum moisture content, it was decided to add enough water, in this series of experiments, to facilitate the determinations. For the hydrogen electrode work a suitable quantity was found to be 2 cc. per gram of dry soil. The same quantity was used for the colorimetric, or indicator, work, though it was much more than is necessary. For expediency the soil was air dried, though in some cases the drying was interrupted when the soil was still somewhat damp. Without forcing or grinding, the soils were put through a coarse sieve to remove sticks and stones, and in four cases through a one-millimeter sieve in the same way in order to remove fine woody material which interfered with the pipetting of the fluid after the use of the centrifuge.

Twenty-two soils were taken for investigation. They included samples of muck, sandy loam, loam, silty loam, silt loam, clay loam, and clay. Some reacted strongly acid to litmus paper, some neutral, and some alkaline.

The hydrogen ion concentration has been expressed, in the customary manner, as the hydrogen-ion exponent of Sörensen.[6]

ELECTROMETRIC DETERMINATIONS

In figure 1 is shown the electrode vessel together with the electrode in position, the soil and water mixture and the junction between the

[5] Biochem. Ztschr., **68**: 206. 1915.
[6] Biochem. Ztschr., **21**: 131. 1909.

saturated potassium chloride solution and the soil extract. By means of a motor the vessel could be swung about an axis at x; during the motion the body of the electrode vessel turned from an inclination of 3° to the horizontal to an inclination of about 33° to the horizontal. The electrode vessel had a capacity of about 65 cc., measured from the brim to the stopcock.

Fifteen grams of dry soil were introduced into a test-tube 17 by 3 cm., 30 cc. of distilled water were added, and the mixture was well shaken and permitted to stand about 10 to 20 minutes for sedimentation.

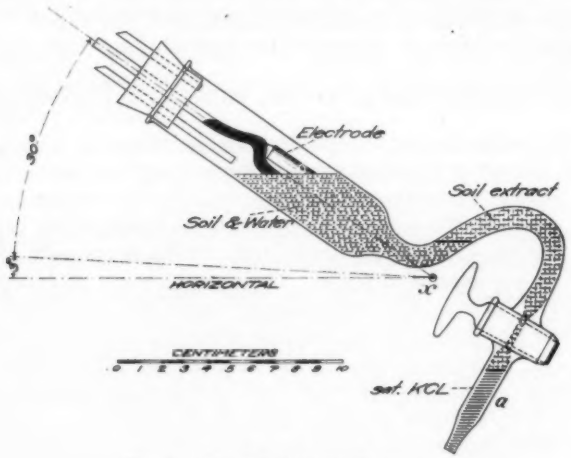


Fig. 1. The filled electrode vessel.

The neck of the electrode vessel, including the bore of the stopcock, was filled with a portion of the soil extract so obtained and the stopcock was then closed. The end-tube a was filled with saturated potassium chloride solution by means of a capillary pipette. The rest of the soil mass was now well agitated and immediately poured into the vessel, which was then fastened to the shaking device. A rubber tube, filled with the saturated potassium chloride solution which led to the calomel electrode through a closed, ungreased stopcock, was joined to the tube a, and the vessel was closed with a well-fitting rubber stopper carrying the electrode and tubes for the entrance and exit of hydrogen. A volume of about 140 cc. of dry hydrogen, electrolytically generated from caustic potash solution with iron electrodes, was rapidly swept through the

space over the soil mixture, the current of hydrogen was stopped by closing the exit, and the vessel was shaken 10 to 20 times. In order to remove residual atmospheric nitrogen another portion of hydrogen was passed through in the same way, and after shaking again 10 to 20 times the hydrogen entrance was also closed and the vessel shaken at the rate of 70 to 90 complete swings per minute for five minutes. The motor was stopped, the potassium chloride contact was made in the tube *a*, the shaking was started again, and the electromotive force of the combination of the electrode with a saturated KCl calomel electrode[7] was determined at once. The vessel was shaken continuously during the measurement, according to the proposal of Hasselbalch for measurements on biological fluids,[8] this procedure being especially advantageous for work with fluids poor in regulating capacity. From this difference of potential and the temperature the hydrogen-ion exponent was calculated from the figures given by Michaelis.[9] The temperature was observed in a bottle which took the place of the usual potassium chloride trough; it remained between 25.5° and 28.5°C. during all the determinations. Tests of the calomel electrode on regulator mixtures of known exponents showed no error due to the calomel electrode. The hydrogen electrode is shown in figure 2. A large sheet of plati num was used which measured 2.54 cm. by 3.3 cm. It was freshly coated with palladium black for each determination after complete removal of the previous coating. In constructing the hydrogen electrode it was necessary to support the sheet of platinum at both top and bottom, and also to provide leads for the current at two opposite points, in order to secure an even deposit of palladium black. The electrode remained partially (about half) submerged during the shaking.

Fig. 2. Hydrogen electrode.

The arrangement used for measuring the potentials was that described by Hildebrand.[10] A capillary electrometer was used as a null-point instrument. A voltmeter was used which read directly to 20 millivolts.[11] The potential could be estimated accurately to 2 millivolts and often to 1 millivolt. The voltmeter was calibrated

[7] Michaelis and Davidoff, Biochem. Ztschr., **46**: 131. 1912.
[8] Biochem. Bulletin, **2**: 367. 1913.
[9] Die Wasserstoffionenkonzentration, 157. 1914.
[10] Journ. Am. Chem. Soc., **35**: 847. 1913.
[11] For further work a high-grade potentiometer will be available.

against an accurate potentiometer with the kind assistance of Dr. William Mansfield Clark, of the Bureau of Animal Industry.

In order to see whether a substantially correct potential had been obtained, the shaking was continued after the first measurement for 5 to 9 minutes longer and the potential was determined again in the same way. This was done in all cases but one. In 7 cases the potential observed was the same, in 10 cases it had fallen (1 fall of 3, 1 of 2, and 8 of 1 millivolt), and in 4 cases it had risen (1 rise of 3, and 3 of 1 millivolt). No relation could be seen between the changes and the values of the potential. A possible interpretation of the falls of potential is that a more complete saturation of the water with acid substance was attained during the second shaking. The rises may have been due to hydrolyzation of soil minerals. No difficulty was encountered even with the measurement of soils which gave neutral or alkaline results.[12]

COLORIMETRIC DETERMINATIONS

Fifteen grams of dry soil were treated in a centrifuge tube of 60 cc. capacity with 30 cc. of distilled water. After thorough wetting of the soil was accomplished by means of shaking or of slight stirring the tube was closed by the hand and violently shaken fifty times. Not more than 8 soils were thus treated at a time. The entire determination was now carried out without delay. The tubes were centrifuged for 10 to 20 minutes. The supernatant fluid in some cases was almost clear, in many cases there was considerable turbidity, and in a few cases there was a heavy turbidity together with a yellowish color. With a pipette provided with a rubber tube and mouthpiece 15 to 20 cc. were withdrawn, and 5 cc. were put into each of 3 test-tubes. Indicator solution was added and admixed and the color so developed was compared with the colors obtained on adding the same quantity of the same indicator solution to tubes containing 5 cc. of various "regulators" of known hydrogen-ion concentrations. With all fluids it was possible to make a satisfactory comparison by means of at least one indicator, and with most fluids it was possible to make an independent comparison with a second indicator. This was done whenever possible. When the color which developed in the soil extract was the same as that in a particular regulator, the hydrogen-ion exponent of that regulator was

[12] In preliminary experiments the use of soil and water in such quantities that agitation of the mass during shaking was inefficient was found to prevent the attainment of approximately equilibrium conditions within five minutes.

recorded as the result. When the color was intermediate between the colors of two successive regulator tubes, the value of the hydrogen-ion exponent was estimated to one-half or one-third of the interval.

TABLE I

NO.	SOIL	ELECTROMETRIC RESULTS		COLORIMETRIC RESULTS			MEAN, BOTH METHODS
		Potential*	Hydrogen-ion exponent	Indicator	Hydrogen-ion exponent	Mean indicator result	
1	Loam, from Maryland	515	4.55	t-br-ph-s-pht	4.3		
				methyl red	4.3	4.3	4.4
2	Silty loam, from Maine	524	4.7	t-br-ph-s-pht	4.4		
				methyl red	4.6	4.5	4.6
3	Loam, from Maine	527	4.75	methyl red	5.15		
				dipropyl red	5.2	5.2	5.0
4	Sandy loam, from Virginia	532	4.8	methyl red	4.9		
				dipropyl red	4.9	4.9	4.85
5	Silty loan, from Maine	542	5.0	methyl red	5.2		
				dipropyl red	5.4	5.3	5.15
6	Sandy loam, from Virginia	546	5.1	methyl red	5.2		
				dipropyl red	5.25	5.2	5.2
7	Silty loam, from Virginia	549	5.1	methyl red	5.2		
				dipropyl red	5.4	5.3	5.2
8	Silty loam subsoil, from Maine	556	5.2	methyl red	5.3		
				dipropyl red	5.6	5.45	5.3
9	Silt loam, from Maine	561	5.3	methyl red	5.6	5.6	5.45
10	Silty loam, from Virginia	567	5.4	methyl red	5.2		
				dipropyl red	5.3	5.25	5.3
11	Silt loam, from Virginia	571	5.5	methyl red	5.5		
				dipropyl red	5.6	5.55	5.5
12	Loam subsoil, from Maine	576	5.6	methyl red	5.5		
				dipropyl red	5.7	5.6	5.6
13	Silt loam, from Maine	591	5.8	methyl red	5.75		
				br-th-s-pht	5.75	5.75	5.8
14	Muck, from Maine	591	5.8	dipropyl red	5.9		
				br-th-s-pht	5.9	5.9	5.85
15	Muck, from Maine	594	5.9	br-th-s-pht	5.45	5.45	5.7
16	Silt loam, from Maine	628	6.45	br-th-s-pht	6.05	6.05	6.25
17	Clay loam subsoil, from Maine	644	6.7	br-th-s-pht	6.4		
				ph-s-pht	6.95	6.7	6.7
18	Silt loam, from Virginia	666	7.1	br-th-s-pht	6.9		
				ph-s-pht	7.0	6.95	7.0
19	Clay, from Montana	727	8.1	ph-s-pht	8.0		
				ph-pht	7.9	7.95	8.0
20	Loam, from Utah	736	8.3	ph-s-pht	8.1		
				ph-pht	8.1	8.1	8.2
21	Clay, from Montana	739	8.3	ph-s-pht	8.2		
				ph-pht	8.2	8.2	8.25
22	Loam, from Utah	763	8.7	ph-s-pht	8.4		
				ph-pht	8.5	8.45	8.6

* Potential in millivolts, corrected by means of calibration curve.

Twenty regulator mixtures were prepared for the work, the exponents were determined electrometrically and the colorimetric work was done while the solutions were fresh. The reaction varied from one tube to the next in the series by a step of about 0.3 in the value of the exponent. From the exponent 3.5 to 5.1 the regulators were prepared from a given quantity of n/10 sodium hydrate and decreasing quantities of n/2 acetic acid and water. The concentration of the sodium acetate formed in the mixing was m/200 in all cases. From 5.3 to 6.8, mixtures of m/10 potassium acid phosphate and m/10 sodium hydrate and water were used which had the same concentration of primary and of secon lary phosphate as prescribed by Sörensen[13] and were thus m/15 with phosphate; and from 7.1 to 9.4, other mixtures of the same two solutions were used (without addition of water), in which the concentration of phosphate decreased from m/16 to m/20, owing to the dilution involved in the use of sodium hydrate instead of the disodium phosphate used by Sörensen.

The following six indicators were used: (1) tetrabromphenolsulfonephthalein (abbreviated in the table to t-br-ph-s-pht), 3 drops from a capillary pipette of a solution of 0.1 gram in 250 cc. alcohol; (2) methyl red, 2 drops of a solution of 0.1 gram in 300 cc. alcohol and 200 cc. water; (3) dipropyl red, 4 drops from a capillary pipette of a solution made in the same way as the methyl red; (4) bromthymolsulfonephthalein (br-th-s-pht), 6 drops from a capillary pipette of a solution of 0.1 gram in 200 cc. alcohol; (5) the sodium salt of phenolsulfonephthalein (ph-s-pht), 1 drop of a 0.06 per cent aqueous solution; and (6) phenolphthalein (ph-pht), 1 drop of a 0.5 per cent solution in 50 per cent alcohol. The first, third, and fourth are new indicators recently prepared and described by Lubs and Clark.[14] Solutions of these were kindly given to me by Dr. H. A. Lubs. These three new indicators would seem to have considerable value in this type of investigation.

The colorimetric results are given, together with the electrometric results, in the table herewith (Table I).

DISCUSSION OF THE RESULTS

In the table are given the hydrogen-ion exponent for each of the 22 soils as determined by the electrometric method and by the different indicators, and also the mean colorimetric result and the mean of the

[13] Biochem. Ztschr., **21**: 131. 1909; **22**: 352. 1909.

[14] Jour. Wash. Acad. Sci., **5**: 609. 1915.

two methods. The soils are arranged in the order of decreasing acidity. An exponent of 7 means neutrality; a smaller one, acidity; and a larger one, alkalinity. It will be seen that values were obtained between 4.4 and 8.6. Some of the acidities found are rather intense, from a biological point of view. Thus Brünn[15] has found that typhoid bacilli are killed with certainty by exposure for 24 hours to an acidity corresponding to an exponent of 5, and four of the soils show as high, or a higher acidity. One soil gave a neutral result and the four western alkali soils gave distinctly alkaline results.

A study of the results for each soil obtained by the use of the various indicators and by the electrometric method shows that the agreement between the two indicators is very good except in one instance (No. 17), and that the agreement between the colorimetric and the electrometric methods is good in every case. Such agreements show that the two methods give comparable results and give ground for inferring that such results are approximately correct.

It would seem premature at this time to apply the results obtained in this way to the soil as it exists in the field, since carbon dioxide is lost during the drying and the natural "soil solution" is diluted for the determinations. Nevertheless it may well happen that the errors so introduced (from a field standpoint) are not great enough to obscure the differences observable between different soils. Further work will be required to ascertain whether this is the case.

SUMMARY

Procedures have been devised for the electrometric and colorimetric determination of hydrogen-ion concentration in soil admixed with two parts of water. Twenty-two soils of various types and reactions were examined by means of these procedures. The hydrogen-ion exponents so determined were from 4.4 to 8.6. Some of the values are acid, some nearly neutral, and some distinctly alkaline. Of the acid values some represented rather intense acidity.

In 19 cases two different indicators could be used for the colorimetric test, and in these cases there was a good agreement between the two results so obtained. In all cases there was a good agreement between the electrometric and the colorimetric

[15] Dissertation, Berlin, 1913; quoted by Michaelis in the book cited above.

results. Such agreements show that the two methods give comparable results and give ground for inferring that such results are approximately correct.

CONTINUATION OF EXPERIMENTS

The experimentation is being continued. Special effort will be made to develop the colorimetric method into a convenient and practical test and to determine its reliability as applied to soils under field conditions.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

GEODESY.—*Triangulation in West Virginia, Ohio, Kentucky, Indiana, Illinois and Missouri.* A. L. BALDWIN. U. S. Coast and Geodetic Survey Special Publication No. 30. Pp. 67. 1915.

This publication contains the positions of 369 triangulation stations which lie within the limits of the six states mentioned in the title, and most of which form that part of the Transcontinental Triangulation extending from the Atlantic to the Pacific. The publication supplements the information given in Special Publication No. 4 which appeared in 1900 and contained features of special interest to scientists. Positions are there given of only the principal stations and only a few of them are described. Since the appearance of Special Publication No. 4 the United States Standard Datum, called the North American Datum since its use by Mexico and Canada, was adopted and it became necessary to place the old positions on that datum. In Special Publication No. 30 there are given the geographic positions, on the North American Datum, of all stations in the area covered, together with all available descriptions of these points.

In addition to the above-mentioned data, this publication gives the results of a trigonometric connection made in 1914 between the detached pieces of triangulation to the north and south of Louisville, Kentucky. It includes also the results of a primary base line measured in 1879 with six-meter contact-slide bars. Such apparatus is no longer used in the field in the United States, as the long invar tapes or ribbons have recently superseded all forms of bars in base line measurements. The field work covered by this publication was done between 1871 and 1914, but all details are omitted, except for the primary triangulation done in Indiana in 1914.

Aside from its scientific interest, the volume has a large practical

value, as it offers to the engineer and map maker a large number of points determined trigonometrically and correlated on one geodetic datum. These stations or points are a part of a framework, composed of the connected triangulation of the country, from which the state, county or private surveyor may extend triangulation of a lower grade for the control of detailed work. A. L. B.

GEOLOGY.—*The Pleistocene of Indiana and Michigan and the history of the Great Lakes.* FRANK LEVERETT and F. B. TAYLOR. U. S. Geological Survey Monograph 53. Pp. 529, maps and illustrations. 1915.

This monograph describes the glacial features of Indiana and the southern peninsula of Michigan and the great glacial lakes which bordered the receding ice front. Brief mention is also made of related glacial and lake features in Ohio, New York, Ontario and Wisconsin.

Glacial drift of Illinoian age extends 50 to 100 miles south of the border of the Wisconsin drift in Indiana and probably underlies the whole extent of the Wisconsin drift in the area described. Till of pre-Wisconsin age has been penetrated by borings over considerable areas in the Saginaw valley.

At its maximum extension the Wisconsin ice sheet was not very definitely lobate but by the time the recession of the ice margin had progressed 75 to 100 miles the Huron-Erie lobe on the east began to be sharply separated from the Lake Michigan lobe on the west and a well defined reentrant appeared between them. Terminating at first in northern Indiana, this reentrant rapidly widened and extended northeastward into Michigan until the Saginaw lobe became a distinct feature. All three of the ice lobes retreated in an oscillating manner and made a series of moraines. Readvances appear generally to have been relatively small, but in one or two cases they amounted to at least 20 to 25 miles.

The report deals at length with the development and relations of the three lobes and their effects on drainage and on the great lakes which gathered in the great valleys whose natural outlets were temporarily obstructed by the ice.

Among the moraines the Port Huron morainic system is particularly well marked, being identifiable from eastern Wisconsin to western New York. This system appears to mark a longer step of retreat and readvance than the average. During a later stage drumlins were formed over a considerable area around Charlevoix, Michigan, and a few in other places.

The rivers that issued from the great reentrants of the ice front carried enormous quantities of sediment, the coarser parts of which were spread over extensive areas in front of the ice. The soils thus produced are lower in fertility than those of the intervening moraines and till plains.

The larger lakes began with glacial Lake Maumee which first appeared as a small crescent-shaped body of water bordering the ice front with its outlet at Fort Wayne, Indiana. In a similar manner glacial Lake Chicago soon appeared at the south end of the Lake Michigan basin. The bearing of certain facts observed in Ohio on the attraction of the ice sheet upon the lake waters near it is discussed in connection with Lake Maumee. Remarkable ice ramparts formed in connection with the same lake are also described. With further recession of the ice these lakes expanded northward until Lake Maumee found a lower outlet westward across the "thumb" of Michigan 50 miles north of Detroit. About this time a lake made its appearance in the Saginaw valley and from this point the history of lake waters is involved in considerable complexity. This complexity arose mainly from the oscillation of the ice front, and from its relation to certain parts of the land whose form and relief caused them to become barriers at climaxes of readvance but not at climaxes of recession. These barriers were: (1) the broad low ridge forming the "thumb" of Michigan, and (2) the northward sloping front of the highlands south of Syracuse, N. Y. In both of these regions, first on the "thumb" and then near Syracuse, outlets for the lake waters were alternately opened and closed by the oscillating ice front and the level of the waters was alternately lowered and elevated correspondingly. Following Lake Maumee, the waters underwent a number of changes of level and of outlet, forming successively Lakes Arkona, Whittlesey, Wayne, Warren, and Lundy.

At length the lowland between the Huron and Erie basins was left dry and St. Clair and Detroit rivers began their post-glacial existence. Similarly the lowland between Lakes Erie and Ontario emerged and Niagara River and the great cataract came into being. Soon after the appearance of early Lake Algonquin in the south half of the Huron basin the waters in the three upper basins, those of Superior, Michigan, and Huron were united, forming the great Lake Algonquin, the largest of the glacial lakes of the region. Twice the recession of the ice opened outlets for Lake Algonquin, but on both occasions these were closed by differential elevation of northern lands. The first was at Kirkfield, Ont., and the second at North Bay, Ont. The uptilting of the land at

the north is recorded in northward splitting and divergence of breaches and the relatively rapid rate of the uplift is shown by a wide interval in the north below the upper group of Algonquin beaches.

The opening of the outlet at North Bay marks the final disappearance of the ice sheet from the Great Lakes region and the end of its influence in lake history. At this stage the upper lakes, known as Nipissing Great Lakes, were not very different from the present Great Lakes except that their outlet was eastward through the Mattawa and Ottawa rivers to the sea near Ottawa. Uplift of the land finally changed the outlet of these post-glacial lakes from North Bay to Port Huron and established the present system.

In the closing chapter the possible causes of the deformation of shore lines, such as resilience with ice removal following depression by ice weight, eustatic movements, and crustal creep are considered, but final conclusions are not reached.

F. B. T.

GEOLOGY.—*Contributions to Economic Geology, 1913, Part II, Mineral Fuels.* M. R. CAMPBELL, and DAVID WHITE. U. S. Geological Survey Bulletin 581. Pp. 187, 11 plates, 6 text figures. 1915.

This volume contains two classes of reports on occurrences of oil and coal: (a) Short reports giving comparatively detailed descriptions of fuel resources that have economic interest but are not of sufficient importance to warrant a lengthy report; (b) preliminary reports on economic investigations, the results of which are to be published later in more detailed form. The papers included in the volume are the following:

WOODRUFF, E. G., and DAY, D. T. *Oil shale in northwestern Colorado and northeastern Utah.*

LUPTON, C. T. *Oil and gas in the western part of the Olympic Peninsula, Washington.*

BARNETT, V. H. *The Moorcroft oil fields, Crook County, Wyoming.*

BARNETT, V. H. *Possibilities of oil in the Big Muddy Dome, Converse and Natrona Counties, Wyoming.*

PACK, R. W., and ENGLISH, W. A. *Geology and oil prospects in Waltham, Priest, Bitterwater, and Peachtree Valleys, California.*

WEGEMANN, C. H. *The Coalville coal field, Utah.*

E. S. B.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE GEOLOGICAL SOCIETY OF WASHINGTON

The 298th meeting was held in the lecture room of the Cosmos Club on October 27, 1915.

INFORMAL COMMUNICATIONS

G. F. LOUGHLIN described an occurrence of hübnerite, wolframite, pyrite, etc., at Leadville, in deposits intermediate in nature between contact metamorphic deposits and ordinary veins.

W. F. HILLEBRAND exhibited a liquid alloy composed mostly of gallium, with a small percentage of indium and zinc. This had been produced in a zinc metallurgical plant, appearing as drops sweated out of zinc-lead dross-plates. It was learned by correspondence with the manager of the works that the particular ore from which it had been derived was uncertain and that in any case the amount which could be produced was probably small.

In reply to questions from SPENCER, MARTIN, and WELLS, Hillebrand said that at present there was no use to which gallium was put. It has been obtained previously from zinc ores and indications of its presence were often found in spectroscopic work.

REGULAR PROGRAM

E. T. ALLEN: *Chemical studies in copper sulphide enrichment.* It was shown from a study of the copper sulphides that chalcocite was a mineral of variable composition, made up of cuprous sulphide with a varying amount of dissolved cupric sulphide. There are two crystalline forms of cuprous sulphide, with a transition point at 91°. Only the lower temperature form has so far been found in nature. It was explained how the system Cu-Fe-S was being studied through the dissociation pressure curves of the various sulphides of Cu and Fe. A preliminary study of gossans has been made, with the result that all appear to be amorphous and to show a thermal behavior similar to limonite. A comparative study of the rates of oxidation of the commoner sulphides, in pure condition, has been made and much attention has been given to the chemical study of the enrichment process. The action of copper sulphate solutions on the most important sulphides has been studied at 200°, 100°, and 40°. In all cases the final product has been cuprous sulphide. Covellite, and chalcocite con-

taining dissolved cupric sulphide, appear as intermediate products. The logical conclusion from the data is that secondary chalcopyrite, bornite, and covellite are earlier stages of a process which was interrupted before it was complete. Many reactions, such as the synthesis of bornite and chalcopyrite in the wet way, have been worked out.

Discussion: G. F. LOUGHLIN inquired regarding rate of oxidation of galena in comparison with sphalerite. Allen replied that with galena the action is rapid at first but an insoluble coating soon forms and action ceases. E. S. BASTIN spoke of a phenomenon he had observed in field work. In a certain type of enrichment covellite, chalcocite, etc. form; in another type only chalcopyrite. In the latter case galena, sphalerite and carbonates are prominent accompanying minerals. He asked Allen if he had any explanation. Allen replied that his experiments did not offer any suggestion. He emphasized the fact that the end product of true equilibrium between sulphide ores and copper sulphate solutions is not chalcopyrite but chalcocite. A. C. SPENCER asked if it were possible that in processes of secondary enrichment migration of copper in carbonate solutions had taken place. Allen thought that an obstacle to such a conception was the lack of the necessary oxidizing agent.

C. WYTHE COOKE: *The age of the Ocala limestone of Florida.* The Ocala limestone, which has heretofore been thought to represent the concluding stage of the lower Oligocene (Vicksburg group) and to overlie the Marianna and "Peninsular" limestones, occurs at Marianna, Florida, lying unmistakably beneath the Marianna limestone, which is of Vicksburg age. Critical study of the list of fossils from Ocala published by Dall in 1903 shows that the formation is of upper Jackson (Eocene) age. The "Peninsular" limestone is in large part identical with the Ocala but may include other formations.

Discussion: R. S. BASSLER spoke of the great difficulties encountered in working out stratigraphic relations in the Southern States, due principally to lack of satisfactory outcrops. T. WAYLAND VAUGHAN referred to some of the structural relations which had led former workers astray. One of the chief factors was the presence of an erosion unconformity and the lack of certain members in certain type sections. L. W. STEPHENSON thought that one of the chief points brought out by the paper was the necessity for very careful paleontologic work.

C. N. FENNER, *Secretary.*

The 299th meeting was held in the lecture room of the Cosmos Club on November 10, 1915.

INFORMAL COMMUNICATIONS

W. T. SCHALLER described briefly a kaolinite from Oklahoma which was of very pure composition, but remarkable for intumescence before the blowpipe.

REGULAR PROGRAM

EDGAR T. WHERRY: *Notes on the geology near Reading, Pennsylvania, (Illustrated.)* The Cambrian, Ordovician, and Triassic formations of the region, and their structures, were briefly described. The Cambrian comprises a quartzite and two limestones; the Ordovician, limestone, cement-rock, and shale; and the Triassic, shale, sandstone, conglomerate basalt, and diabase. The beds are greatly disturbed, being in places overturned to 45°, elsewhere intricately folded, and cut by three systems of faults: thrust-faults from the southeast, dating from late Ordovician time; normal faults with the drop on the southeast, which formed during the Triassic deposition; and normal faults crossing the other two systems nearly at right angles, which were developed at the close of Triassic time.

Discussion: G. W. STOSE referred to the remarkable amount of faulting exhibited in this area. In an area 20–30 miles to the south, whose structure had been worked out, there is almost none. He remarked also on the well-defined characteristics of the Martinsburg shale in this section. In an adjacent section it is difficult to distinguish between the Martinsburg shale and certain shaly strata in the Cambrian.

J. W. GIDLEY: *The relations of vertebrate fossils to stratigraphy.* (No abstract.)

N. H. DARTON: *Some geologic features of southeastern California. (Illustrated.)* The results of a reconnaissance made near the line of the Santa Fé Railroad from Needles to Cajon Pass in 1906 and 1914 were outlined. Some of the facts have been published in the Guide Book to Geology, etc., of the Santa Fé Railroad, but many technical details regarding rocks, structure, and fossils were necessarily omitted from that publication. Six general series of rocks were found: (1) A widely exposed basement of pre-Cambrian granites and schists, mostly appearing in high ridges; (2) a succession of Paleozoic rocks which yielded Cambrian to Carboniferous fossils at several localities, notably in Iron Mountain and its northern continuation, Providence Mountain, to which a side trip was made from Kelso; (3) intrusive quartz-monzonites and similar rocks cutting the Paleozoic strata and altering limestones to marbles; (4) a thick series of Tertiary (Rosamond, etc.) volcanic rocks, largely breccia, tuffs, ash, and sediments, with interbedded effusive sheets, and some intrusive masses; (5) the valley fill of the desert plain, with lake beds and salt, gypsum, etc.; (6) recent volcanic cones and flows, notably the very fine examples near Amboy and Pisgah. Many details of structure were determined, but it was found that most of the ridges and valleys were not closely related to faults as popularly supposed.

Discussion: F. C. SCHRADER inquired whether it was possible to make correlations among the various volcanic series of different sections; also as to the manner in which mineralization was associated with the igneous rocks. Darton replied that the volcanic rocks of the younger series

were variable, so that successive beds could not be identified individually but the general history and succession could be worked out. Mineralization seems to be associated with igneous rocks of all descriptions, but no very important mines have been developed. T. WAYLAND VAUGHAN spoke of the faulting and inquired if the great block faulting of the West Indies found a parallel in southern California. He had formed the impression from talks with R. T. Hill that such was the case. Darton replied that in his work the details of faults had not been determined. He had found, however, that the topographic lineaments of the region were not due to faulting.

C. N. FENNER, *Secretary.*

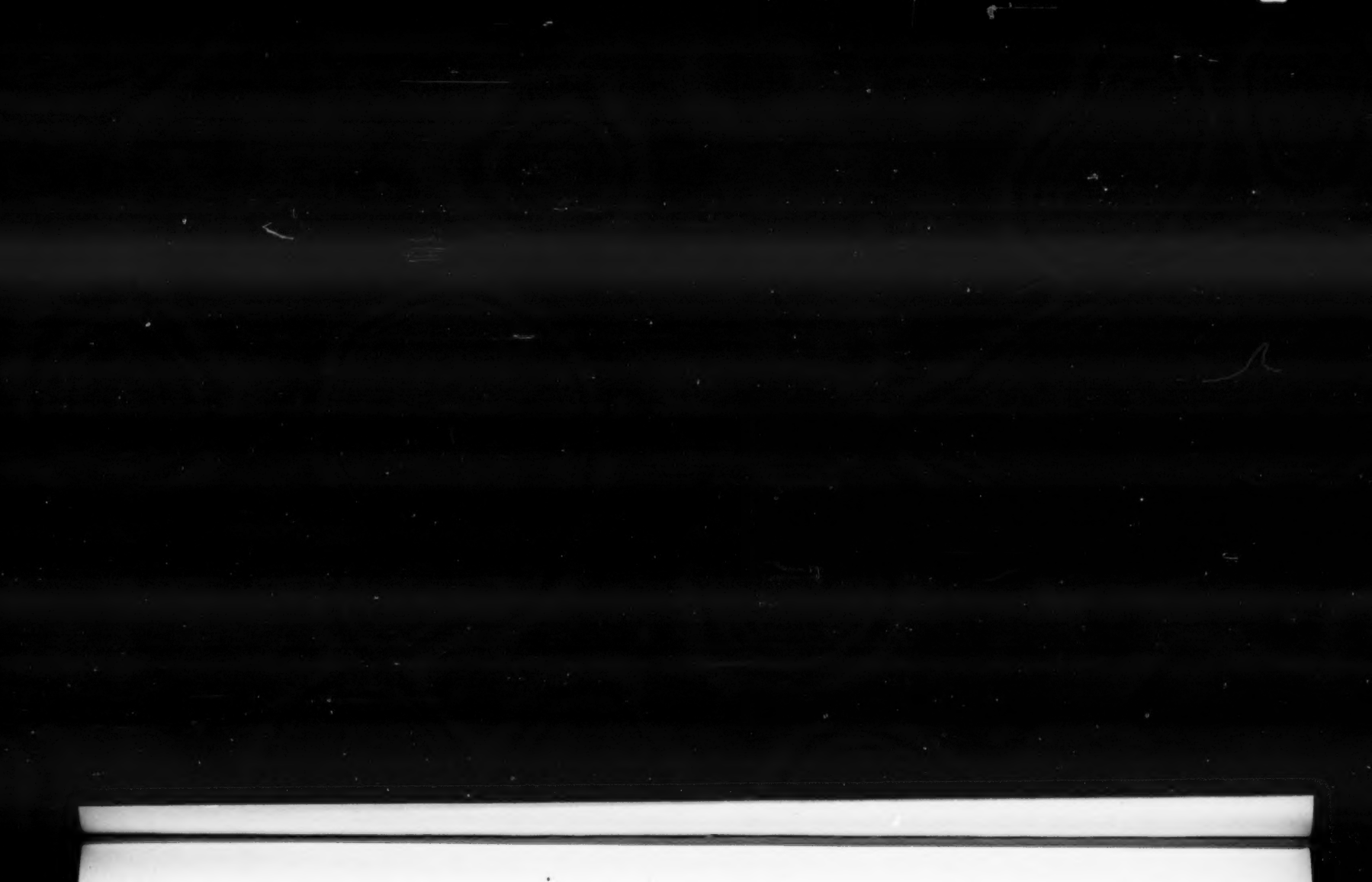
THE BIOLOGICAL SOCIETY OF WASHINGTON

The 544th meeting of the Society was held at the Cosmos Club, Saturday, November 6, 1915 with President Bartsch in the chair; 90 persons present.

On recommendation of the Council, Gilbert F. Bateman, Trinidad, Colorado was elected to active membership.

The first paper of the regular program was by O. P. HAY: *A new Pleistocene sloth from Texas.* Dr. Hay discussed the finding in Texas of a new member of the genus *Nothrotherium.* This discovery extends the range of the genus from South into North America. The specimen was exhibited and remarks were made on the interrelationships and distribution of the living and fossil American Edentates.

The second paper was by J. N. ROSE: *Botanical explorations in South America.* Dr. Rose gave an account of his botanical explorations in South America. He outlined first the field work which he and Dr. N. L. Britton had planned in connection with the cactus investigations of the Carnegie Institution of Washington, and then described the great cactus deserts of South America which he had visited. During his last trip to South America he spent six weeks in the state of Bahia, Brazil, six weeks in the state of Rio de Janeiro, Brazil, and three weeks in Argentina. Large collections were obtained and many living plants were sent back to the United States for cultivation, the living collection being now on exhibition in the New York Botanical Garden. Several remarkable generic types of cacti were discovered. Dr. Rose's paper was illustrated by numerous lantern slides of the regions visited and of cacti in their native environment, and by many interesting botanical specimens.

The last paper of the evening was by L. O. HOWARD: *Some biological pictures of Oahu (Hawaii).* Dr. Howard showed a large number of lantern slides from photographs made by him during a short stay on the island of Oahu during the past summer. Special emphasis was laid on those which dealt with agricultural problems and economic entomology.

M. W. LYON, JR., *Recording Secretary.*